A STUDY OF LEAST-WEIGHT PROPORTIONS OF RAILWAY BRIDGE TRUSSES

BY

JOSEPH LEE WALING

B.S.C.E., Purdue University, 1938
M.S.E., Purdue University, 1940

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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A STUDY OF LEAST-WEIGHT PROPORTIONS OF RAILWAY BRIDGE TRUSSES

Since the beginning of scientific design of bridges, engineers have considered the problem of economy in bridge building. While this branch of engineering is an old one and much work has been done in solving its economic problems, still more remains to be done.

Studies on economic bridge design and construction involve many factors including costs of materials, fabrication, transportation to the site, erection, and maintenance. All of these are influenced by the choice of materials, the choice of general arrangement of the whole structure, the over-all proportioning of the separate structural frameworks, the proportioning of details, the provisions for erection and maintenance, and any additional provisions for a pleasing and safe appearance.

One of the important economic factors in bridge construction, and one which lends itself to mathematical investigation in design, is the quantity of materials used in the structure. It is influenced greatly by the general proportions chosen for the main structural framework. In the case of truss bridges, the over-all dimensions of the main trusses, such as the depth of truss and the number of panels for a given span and loading, have a considerable influence upon the saving of material in the superstructure.

The objects of this study are twofold; namely,

1. To develop a sound mathematical procedure, founded upon modern design specifications, for the determination of least-weight proportions of bridge trusses; and
2. To apply the mathematical procedure to investigate least-weight proportions for a series of railway bridge trusses, including both parallel- and polygonal-chord trusses.

The original works on this subject by American engineers

Whipple, Pratt, Adler, Emery, Searles, DuBois, Lundie, Waddell, and Jackson and by European engineers Melan, Angst, Voigt, and Erdmann are summarized and referenced. This historical summary clearly indicates trends in the thinking by engineers of different nationalities. Several early Americans attempted theoretical investigations of increasing complexity and accuracy until 1895 when Waddell expressed his opinion of such mathematical calculations. Thereafter, the mathematical approach to the problem was employed primarily by Europeans — mostly by German engineers. Americans came to rely upon results of practical experience or upon a great number of actual designs to study the question and to arrive at empirical formulas for most favorable proportions of trusses. Nearly all of the past studies have pertained to various types of parallel-chord trusses; almost no theoretical work has been done to determine least-weight proportions of polygonal- or curved-chord trusses.

The procedure in this study consists of the adaptation of the mathematical theory of maxima and minima to the determination of the depth, or the depths in the case of curved-cord trusses, at which the volume of metal in the bridge truss becomes a minimum. This procedure is complicated by the necessity of conforming to all of the requirements of modern design specifications. The assumptions and approximations upon which the calculations are based and the resolution of the complications interspersed by the design specifications are discussed in detail. General volume formulas and derivative equations for Pratt and Warren, parallel- and curved-chord trusses of six, eight, and ten panels are included in the Appendix.

Calculations performed to determine least-weight proportions and theoretical least weights of through-type double-track, open-timber-deck railway bridge trusses having sixty-eight different combinations of truss type, panel length, span length, and live load lead to the following conclusions for those types of trusses:

1. It is entirely feasible to apply basic mathematical pro-

cedures to the determination of least-weight proportions and least weights of bridge trusses.

2. Least-weight depths of Pratt parallel-chord trusses designed according to American Railway Engineering Association specifications for E-60 live load are given approximately by the formula

$$d = L(0.381 - 0.0185n); \qquad (168 \leqslant L \leqslant 300), \quad (6 \leqslant n \leqslant 10)$$

where L is the span length in feet and n is the number of panels.

3. Least-weight depths of Warren parallel-chord trusses designed according to AREA specifications for E-60 live load are given approximately by the formula

$$d = L(0.362 - 0.016n); \qquad (168 \leqslant L \leqslant 300), \quad (6 \leqslant n \leqslant 10).$$

4. Least-weight depths of Pratt curved-chord trusses designed according to AREA specifications for E-60 live load are given approximately by the formulas

$$\left.\begin{aligned} d_1 &= L\left(-0.187 + 0.0105n + \frac{2.12}{n}\right) \\ d_2 &= 0.27L \end{aligned}\right\}; \qquad (216 \leqslant L \leqslant 300), \quad (6 \leqslant n \leqslant 10)$$

where d_1 is the depth at the first interior panel point of the truss, d_2 is the depth of truss at midspan, and L and n are the same as given above.

5. Least-weight depths of Warren curved-chord trusses designed according to AREA specifications for E-60 live load are given approximately by the formulas

$$\left.\begin{aligned} d_1 &= L(0.350 - 0.0225n) \\ d_2 &= 0.25L \end{aligned}\right\}; \qquad (216 \leqslant L \leqslant 300), \quad (6 \leqslant n \leqslant 10).$$

6. Least-weight depths of parallel-chord bridge trusses designed for E-75 live load are about one to two percent

greater than for corresponding trusses designed for E-60 live load.

7. Least-weight depths of curved-chord bridge trusses designed for E-75 live load average about five and one-half percent (ranging from three to nine percent) greater than for corresponding trusses designed for E-60 live load.

8. Pratt and Warren parallel-chord trusses of six panels are almost identical in least weight. At eight and ten panels, Pratt trusses are heavier by six to seven and by nine to eleven percent respectively than corresponding Warren trusses.

9. Warren curved-chord trusses of six panels range from the same in weight to eight percent heavier than corresponding Pratt trusses. The least weights of eight- and ten-panel Warren trusses are practically equal to those of the corresponding Pratt trusses.

These concluding generalizations are intended not as a substitute for but as an aid to engineering judgment. Since engineering design constantly entails compromises between best design and least cost, and since least weight of structure is but one factor in least cost, an engineer cannot correctly use as design equations the approximate formulas given above or the more exact data of the thesis pertinent to least-weight proportions. However, one who knows the least-weight characteristics of a structure is in a much better position to make a judicious compromise between best design and least cost than is one who must guess at this information.

VITA

Joseph Lee Waling was born near Brook, Indiana, on March 17, 1916. Upon graduating from Brook High School in 1933, he was granted a scholarship by Purdue University where he entered the School of Civil Engineering in September, 1933. In June, 1938 he was granted the degree of Bachelor of Science in Civil Engineering, with distinction. He received the degree of Master of Science in Engineering from Purdue University in June, 1940.

He was appointed Graduate Assistant in Applied Mechanics at Purdue University in September, 1938 and Instructor in same department in September, 1940. In April, 1941 he accepted a civil service appointment as Naval Architect (P-2) at Norfolk Naval Shipyard, Portsmouth, Virginia. This work in the Development of Design Section, consisted mainly of launching calculations, strength investigations, and design of ship structures. In October, 1945 he resigned his position as Naval Architect (P-5) to return to Purdue University as Assistant Professor of Engineering Mechanics. In July, 1947 he was promoted to Associate Professor of Engineering Mechanics, a position which he now holds. His work since returning to Purdue has included both teaching and research. Since September, 1951 he has been on sabbatical leave from Purdue University to devote full time to his studies at the University of Illinois. In anticipation of this sabbatical leave, he had taken courses part time at Purdue since September, 1948 and at the University of Illinois since June, 1950.

He is a member of the American Society of Civil Engineers, Society for Experimental Stress Analysis, American Society for Engineering Education, American Association of University Professors, Chi Epsilon, Tau Beta Pi, and Sigma Xi. He is a Registered Professional Engineer in the State of Indiana.